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From:	Deni Chambers Taylor Bennett Josh Otis	**Date:**	March 8, 2010
To:	Keith Bailey Susan Crowley Matt Paque Roy Widmann		
RE:	Technical memorandum: Preliminary Evaluation of Soil Leaching to Groundwater Using NDEP Guidance Tronox LLC, Henderson, Nevada		

INTRODUCTION

This technical memorandum provides a screening evaluation of the potential for leaching of site-related chemicals (SRCs) from soil to groundwater, using the methods presented in the "Soil to Groundwater Leaching Guidance" from the Nevada Division of Environmental Protection (NDEP) dated January 16, 2010 ("guidance"). This screening evaluation of leaching from soil to groundwater was conducted as discussed in telephone discussions between representatives of Tronox, Northgate, and NDEP on February 12, 17, and 23, 2010. Chemicals of potential concern (COPCs) for the soil leaching to groundwater pathway were identified in accordance with the Health Risk Assessment Work Plan (HRA WP; Northgate, 2010). The purpose of this screening is to identify COPCs that that may require addition evaluation, which may include unsaturated zone fate-and-transport modeling.

The guidance outlines a progression of screening criteria that were used to determine which COPCs represent a significant risk to impact groundwater quality and require further study. For metals and radionuclides, Northgate also statistically compared concentrations measured in soil at the Site to regional background levels as discussed with NDEP and described in the HRA WP.

The progression of steps used in this preliminary evaluation to screen COPCs for the soil leaching to groundwater pathway is as follows:

1) ***Background*** (metals and radionuclides only). Concentrations measured at the Site were compared to naturally-occurring background levels (BRC, 2007; BRC and ERM, 2009), in consideration of USEPA guidance (USEPA 1989, 1992b, c), which allows for the elimination of chemicals from further quantitative evaluation if detected levels are not detected above naturally occurring levels. COPCs present at concentrations

consistent with background levels were not carried forward for further analysis, as agreed by NDEP during the telephone discussion on February 17.

2) ***Leaching-based Basic Comparison Levels (LBCLs)***, dilution-attenuation factor (DAF) of 20 (NDEP, 2009). Metals and radionuclides present above naturally-occurring background levels were compared to LBCLs to evaluate the potential soil leaching to groundwater. COPCs that did not exceed LBCLs were not carried forward for further analysis.

3) ***Leaching-based Site-specific levels (LSSLs)***. Northgate calculated LSSLs for compounds present above LBCLs, using the soil-water partition (SWP) equation presented in the guidance, substituting site-specific soil physical and chemical properties and a site-specific DAF for the default LBCL values. COPCs exceeding LSSLs will be individually evaluated to determine the need for additional analysis, including potential unsaturated zone fate-and-transport modeling.

A discussion of the site-specific data and assumptions used in calculating the LSSLs is presented below. This is followed by a summary of the results of the preliminary screening evaluation, including a discussion of additional work needed to evaluate the soil-to-groundwater leaching pathway for metals and radionuclides.

CALCULATION OF LSSLs

LSSLs were calculated using Equations 1 and 2 (SWP) and Equations 3 and 4 (DAF) of the guidance. Measured or estimated Site-specific physical and chemical values were used for the calculations where available. The general methodology used, including known assumptions and limitations of the calculations, is summarized below. Site-specific input parameters used to calculate LSSLs are presented in Table 1. LSSL calculations for each chemical evaluated are presented in Table 2 (metals and radionuclides).

LSSL Calculation

The LSSL equation multiplies a target risk-based groundwater concentration (RBGC) by a DAF that accounts for dilution and mixing of a leachate with groundwater, and a third term which estimates the concentration of a leachate solution in equilibrium with a vadose zone contaminant. The LSSLs thus calculated represent Site-specific estimates of allowable unsaturated-zone concentrations of COPCs that would still be protective of groundwater quality.

Northgate used the following inputs to the LSSL equations:

- ***RBGC***: U.S. Environmental Protection Agency (US EPA) Primary Maximum Contaminant Levels (MCLs) were used for the RBGC, with NDEP Residential Water Basic Contaminant Levels (RWBCLs) substituted for COPCs that do not have an established Primary MCL. LSSLs were not calculated for COPCs that do not have an established RWBCL.

- ***DAF***: The DAF calculation estimates the dilution of a leachate based on mixing with the shallow water-bearing zone (WBZ) in the saturated alluvium (Qal) at the Site. The DAF calculation is discussed separately below.
- ***Leachate Concentration***: For inorganic COPCs, the leachate concentration is calculated using a chemical-specific distribution coefficient (K_d) and physical soil properties (soil porosities and bulk density). Physical soil properties (porosity, moisture content, and bulk density) come from core samples collected from the Qal. Chemical-specific K_d values were selected from several sources, primarily published by the NDEP or US EPA.

DAF Calculation

The DAF expresses the reduction in contaminant concentration that occurs as a soil leachate mixes with, and dilutes into groundwater. The amount of reduction (e.g. the magnitude of the DAF) is dependent on the infiltration rate, contaminant source length, and aquifer hydraulic properties. The DAF is used to calculate LSSLs in the SWP equations (Equations 1 and 2 of the guidance). Northgate used the following input parameters for the DAF:

- ***Infiltration Rate***: The default infiltration rate for undeveloped areas in the vicinity of the BMI Complex of 0.08 inches per year, per the guidance, was used in the DAF calculations.

- ***Contaminant Source Length***: A contaminant-specific source length was not calculated for each COPC evaluated. Instead, a conservative value of 1,500 feet was assigned as the source length for all DAF/LSSL calculations.

- ***Aquifer Hydraulic Properties***: The shallow WBZ at the Site includes the saturated portion of the Qal and the top/unconfined portion of the Upper Muddy Creek formation (UMCf). In the southern (upgradient) portion of the Site (generally, south of the Unit buildings), groundwater in the shallow WBZ is first encountered in the UMCf. North of the Unit buildings, the shallow WBZ "daylights" from the UMCf into the Qal. The thickness of saturated Qal generally increases northward of the Interceptor wells and barrier wall. For the purpose of this preliminary screening evaluation, Northgate calculated the DAF using hydraulic properties of the saturated Qal. An average hydraulic conductivity and hydraulic gradient from measurements conducted at the Site were used. For the aquifer thickness, we chose to use a value of 1 foot to represent a conservative estimation of the thickness of saturated Qal in the main source areas located between the unit buildings and the barrier wall.

Assumptions and Limitations

Northgate has endeavored to calculate these LSSLs using accurate Site-specific input parameters to estimate the allowable residual concentrations of COPCs that are protective of groundwater quality. There are a number of inherently conservative assumptions in the guidance for performing screening-level calculations to evaluate the leaching pathway (i.e., infinite source of COPCs, a continuous source from the surface to the top of the aquifer, and the absence of attenuation in the unsaturated zone). However, it should be noted that there are some limitations and uncertainties in the calculations presented herein that may require additional evaluation.

The statistical comparison of Site soil concentrations with the background dataset (BRC, 2007 and ERM, 2009) is continuing to be evaluated. For this preliminary screening of leaching potential, SRCs were not selected as COPCs for further evaluation if they met all the statistical tests for consistency with background levels (Table 4). In some instances, where the statistical tests did not conclusively yield results consistent with background, the SRCs were included as COPCs for further evaluation. However, these SRCs will continue to be evaluated for consistency with background levels, based on a weight-of-evidence approach. If further statistical comparisons indicate that these SRCs are consistent with background levels, they may be excluded from further evaluation of potential for leaching from soil to groundwater.

The primary sources of uncertainty in the LSSLs are related to soil-water partition coefficients (K_d) and the source length used in the DAF calculation. These are summarized below.

Northgate has worked with NDEP to identify sources for partitioning coefficients, but there are some COPCs for which a range of K_d values have been identified and the LSSLs for these chemicals should be considered provisional. In addition, there are large variations between different published K_d values for some COPCs (e.g., uranium).

Several simplifying assumptions have been made in the calculation of the DAF. A Site-specific infiltration rate has not been calculated, so the default value for undeveloped land is currently used instead. NDEP indicated during the February 17 meeting that the default value of 0.08 inches per year may not be appropriate for the Site, and may need further evaluation. Two Site-specific parameters used in calculating the DAF, source area length and aquifer thickness, vary on a chemical-specific basis as the source location and extent is not consistent for all COPCs. Instead of assigning these values on a chemical-specific basis for this screening evaluation, we calculated the DAF for all LSSLs using conservative values for the source area length of 1,500 feet and an aquifer thickness of 1 foot. These values were chosen to be conservative for the areas of the Site where the sources are primarily located over saturated Qal. Finally, the hydraulic parameters (hydraulic conductivity and gradient) used in calculating DAFs are based on measurements of the saturated Qal only. However, in the southern (upgradient) portion of the Site, the surface of the water table is present in the UMCf rather than the Qal. Additonal evaluation may be needed to identify potential source areas in the southern portion of the Site and compare contaminant concentrations there to LSSLs calculated using UMCf parameters.

There are no RWBCLs for platinum, potassium, sodium, and uranium isotopes, so these metals were not evaluated in the screening-level leaching evaluation. The statistical comparisons of Site platinum concentrations with background levels are still being evaluated.

SCREENING EVALUATION RESULTS AND DISCUSSION

The results of the screening-level evaluation of the soil-to-groundwater leaching pathway for metals and radionuclides are summarized in Table 4. These results are discussed below.

For comparison with the current leaching evaluation, the results of the Phase A leaching evaluation are summarized here. The Phase A evaluation of the soil-to-groundwater leaching pathway considered whether the SRCs were consistent with background levels (using a more limited background dataset available at the time for comparison), and whether SRCs were detected at concentrations above direct contact comparison levels in groundwater.

The results of the Phase A investigation indicated that only the following SRCs were included for further characterization of the soil-to-groundwater leaching pathway during the Phase B investigation (ENSR, 2007):

- Metals, including arsenic, boron, hexavalent chromium, iron, manganese, molybdenum, strontium, and uranium.
- Perchlorate
- Beta BHC
- Hexachlorobenzene
- VOCs

Phase B Metals

The results of comparisons of metals to the background dataset indicated that nickel in Site soils is consistent with background. Therefore, nickel was not considered further in the leaching evaluation.

The following metals were detected in Site soils at concentrations less than the LSSLs (for DAF=96) and are screened from further leaching evaluations on this basis: aluminum, barium, boron, cadmium, hexavalent chromium, copper, iron, molybdenum, strontium, thallium, and zinc.

The following metals were detected in Site soils at concentrations above their respective LSSLs (for DAF=96): antimony, arsenic, cobalt, lead, magnesium, manganese, and mercury.

All detections of antimony above the LSSL, and detections of arsenic in the top ten feet of soil at the Site that exceed the LSSLs are planned to be removed by excavation. No further evaluation of the potential for leaching of antimony from soil to groundwater is recommended. Vadose-zone modeling of arsenic, cobalt, lead, and manganese for evaluation of leaching is not proposed, because concentrations of these metals that exceed LSSLs are present in deeper soils and potentially already in contact with shallow groundwater. Antimony, arsenic, cobalt, lead, and manganese impacts to groundwater will continue to be evaluated.

Vadose-zone modeling using SESOIL is recommended for further evaluation of magnesium and mercury, in accordance with NDEP's leaching guidance.

Perchlorate is an SRC that is known to have leached from soil to groundwater at the Site, and perchlorate in groundwater is being addressed by the existing groundwater treatment system (GWTS). We are continuing to assess transport of perchlorate in vadose zone soil and groundwater.

Radionuclides

The results of comparing radionuclide activities in Site soils to the background dataset indicated that activities of thorium-232, thorium-228, and radium-228 in Site soils are consistent with background levels. All three of these radionuclides are part of the same decay chain. Thorium-232 and thorium-228 are therefore excluded from further analysis and are not proposed for further leaching evaluation. Although the activities of radium-228 in Site soils are consistent with background, radium isotopes are discussed further, below.

An RBGC has not been established for the individual radium isotopes, but an MCL has been established for total radium (5 picocuries per liter [pCi/L]). Therefore, in accordance with NDEP guidance, the total activities of radium-226 and 228 in soil were considered for evaluation of the leaching potential for radium. The total activities of radium-226 and 228 in soil exceed the LSSL of 1.48 picocuries per gram (pCi/g). Therefore, further evaluation of the potential for leaching of total radium from soil to groundwater is recommended (Table 4).

A comparison of individual uranium isotopes (uranium-238, uranium-235, and uranium-234) with the background dataset indicates that they do exceed background levels at the Site. However, because target groundwater activity levels have not been established for individual uranium isotopes, they were not retained for further leaching analysis. In accordance with NDEP guidance (NDEP, 2009), the total uranium concentrations are used instead to evaluate the potential for leaching of these uranium radionuclides. As noted in the summary of the metals evaluation above, total uranium is not present above its LBCL (for DAF=20) in Site soils. Therefore, uranium isotopes are not proposed for further leaching evaluation.

Thorium-230 is part of the uranium decay chain, and was detected above the LSSL (for DAF=96) in Site soil. Therefore, further evaluation of the potential for leaching of thorium-230 from soil to groundwater is recommended.

Vadose-zone modeling of total radium and thorium-230 for evaluation of leaching is not proposed, because activities of these radionuclides that exceed LSSLs are present in deeper soils and potentially in contact with shallow groundwater.

REFERENCES

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ATTACHMENTS

Table 1: Input Parameters for Soil-Water Partition Equation for Calculating Leaching-Based, Site-Specific Levels (LSSLs)

Table 2: Calculation of Leaching-Based, Site-Specific Levels – Metals and Radionuclides

Table 3: Calculation of Dilution Attenuation Factor (DAF) for Saturated Alluvium (Qal)

Table 4: Site-Wide Soil to Groundwater Leaching Evaluation – Metals and Radionuclides

TABLE 1
Input Parameters for Soil-Water Partition Equation for Calculating Leaching-Based, Site-Specific Levels (LSSLs)

Parameter	Description	Units	Site-Specific Value	Default Value	Source
Ct	Screening soil concentration	mg/kg	-- [1]		NDEP Leaching Guidance, chemical specific
RBGC	Risk-based, groundwater criterion	mg/L	-- [1]		USEPA primary MCL, NDEP RWBCL, chemical specific
Kd	Distribution coefficient	L/kg	-- [1]		Chemical specific
Koc	Soil organic carbon-water partition coefficient	L/kg	-- [1]		Chemical specific
foc	Fraction organic carbon	unitless	-- [1]	0.002	NDEP Leaching guidance
θ	soil porosity [1-(ρb/ρs)]	unitless	0.366		Site J&E Model
θw	Water filled soil porosity	unitless	0.154		Site J&E Model
θa	Air filled soil porosity	unitless	0.212		Site J&E Model
H'	Henry's Law constant	unitless	-- [1]		Chemical specific
ρb	Dry bulk density	kg/L	1.703		Site J&E Model
ρs	Soil particle density	kg/L	2.686		Site J&E Model
DAF	Dilution attenuation factor	unitless	96		Site Specific Calculation (see Table 3)

Note:
1: Chemical-specific values are presented in Table 2.

TABLE 2
Calculation of Leaching-Based, Site-Specific Levels
- Metals and Radionuclides

Parameter of Interest	Chemical	Result Unit	LBCL (DAF = 1)[a]	LBCL (DAF = 20)[a]	RBGC (mg/l) or (pCi/l)	RGBC Key	Kd (L/kg)	Kd Ref	DAF	LSSL (mg/kg)	LSSL (mg/kg) or (pCi/g)
Metals	**Aluminum**	mg/kg	7.50E+01	1.50E+03	3.65E+01	N	1500	4	96	5256317	>100% wt/wt
	Antimony	mg/kg	3.0E-01	6.0E+00	6.E-03	M	45	4	96	26	2.60E+01
	Arsenic	mg/kg	1.0E+01	2.0E+01	1.E-02	M	31	1	96	30	2.98E+01
	Barium	mg/kg	8.20E+01	1.64E+03	2.0E+00	M	52	1	96	10001	1.00E+04
	Beryllium	mg/kg	3.0E+00	6.0E+01	4.0E-03	M	650	4	96	250	2.50E+02
	Boron	mg/kg	2.34E+01	4.67E+02	7.30E+00	N	3	2	96	2166	2.17E+03
	Cadmium	mg/kg	4.0E-01	8.0E+00	5.0E-03	M	4300	1	96	2064	2.06E+03
	Chromium (Total)	mg/kg	2.0E+00	4.0E+01	--	--	4300000	1	96	--	--
	Chromium (VI)	mg/kg	2.0E+00	4.0E+01	1.0E-01	M	14	1	96	135	1.35E+02
	Cobalt	mg/kg	3.30E+01	6.60E+02	1.10E-02	N	45	2	96	47	4.74E+01
	Copper	mg/kg	3.52E+01	7.04E+02	1.36E+00	N	35	2	96	4567	4.57E+03
	Iron	mg/kg	7.56E+00	1.51E+02	2.56E+01	N	25	2	96	61542	6.15E+04
	Lead	mg/kg	--	--	1.50E-02	--	900	4	96	1296	1.30E+03
	Magnesium	mg/kg	--	--	2.07E+02	N	4.5	2	96	91201	9.12E+04
	Manganese	mg/kg	3.26E+00	6.52E+01	5.11E-01	N	65	2	96	3193	3.19E+03
	Mercury	mg/kg	1.04E-01	2.09E+00	2.0E-03	M	10	4	96	1.9	1.95E+00
	Molybdenum	mg/kg	3.64E+00	7.27E+01	1.83E-01	N	20	4	96	352	3.52E+02
	Nickel	mg/kg	7.0E+00	1.40E+02	7.30E-01	N	1900	1	96	133158	1.33E+05
	Platinum	mg/kg	--	--	--	--	90	4	96	--	--
	Potassium	mg/kg	--	--	--	--	5.5	4	96	--	--
	Selenium	mg/kg	3.00E-01	6.00E+00	5.0E-02	M	300	4	96	1440	1.44E+03
	Silver	mg/kg	2.00E+00	4.00E+01	1.83E-01	N	110	1	96	1929	1.93E+03
	Sodium	mg/kg	--	--	--	--	100	4	96	--	--
	Strontium	mg/kg	--	--	2.19E+01	N	35	4	96	73774	7.38E+04
	Thallium	mg/kg	4.0E-01	8.0E+00	2.0E-03	M	1500	4	96	288.02	2.88E+02
	Tin	mg/kg	--	--	2.19E+01	N	250	4	96	525790.12	5.26E+05
	Titanium	mg/kg	1.50E+05	3.0E+06	1.46E+02	N	1000	4	96	14017267.45	>100% wt/wt
	Tungsten	mg/kg	4.12E+01	8.23E+02	2.74E-01	N	150	4	96	3944	3.94E+03
	Uranium	mg/kg	1.35E+01	2.70E+02	3.0E-02	M	450	2	96	1296	1.30E+03
	Vanadium	mg/kg	3.0E+02	6.0E+03	1.83E-01	N	1000	4	96	17522	1.75E+04
	Zinc	mg/kg	6.20E+02	1.24E+04	1.10E+01	N	530	1	96	557231	5.57E+05
Radionuclides	Radium-226	pCi/g	--	--	--	--	--	--	96	--	--
	Radium-228	pCi/g	--	--	--	--	--	--	96	--	--
	Radium (Total)	pCi/g	1.60E-02	3.20E-01	5.0E+00	M	3	5	96	1.5	1.48E+00
	Thorium-228	pCi/g	2.30E-03	4.50E-02	1.10E-01	Risk Based	20	5	96	0.2	2.12E-01
	Thorium-230	pCi/g	8.40E-04	1.70E-02	4.20E-02	Risk Based	20	5	96	0.1	8.10E-02
	Thorium-232	pCi/g	2.90E-03	5.80E-02	1.40E-01	Risk Based	20	5	96	0.3	2.70E-01
	Uranium-234	pCi/g	--	--	--	--	--	--	96	--	--
	Uranium-235	pCi/g	--	--	--	--	--	--	96	--	--
	Uranium-238	pCi/g	--	--	--	--	--	--	96	--	--

Notes:
a - From User's Guide and Background Technical Document for Nevada
(BCLs) for Human Health for the BMI Complex and Common Areas, Revis
indoor and outdoor worker soil BCLs.
Boldface chemicals exceed LBCL (DAF=20) in at least one sample.
RGBC Key: C = Cancer endpoint; N = Noncancer endpoint; M = MCL; sat = Saturation Limit; max = Ceiling Limit
Kd References:
1 Kd @ pH=8.0, USEPA, 1996a, Attachment C, Table C4
2 Kd from NDEP Table D-1 (http://ndep.nv.gov/bmi/docs/table_d-1-1109.pdf)
3 Kd from US EPA, 2005, Superfund Chemical Data Matrix, accessed at http://www.epa.gov/superfund/sites/npl/hrsres/tools/perchlorate_a.pdf
4 Kd from Baes III et al 1984, ORNL-5786, Figure 2.31
5 Kd from Appendix E — Soils at the BMI Complex and Common Areas (accessed at http://ndep.nv.gov/bmi/docs/app_e_11-20-09.pdf)

TABLE 3
Calculation of Dilution Attenuation Factor (DAF)
for Saturated Alluvium (Qal)

Parameter	Value	Source
K, hydraulic conductivity (ft/yr)	47,500	Avg. of Interceptor Wells slug test results
i, gradient (unitless)	0.02	Average horizontal gradient
da, aquifer thickness (ft)	1	Representative value for saturated Qal
d. mixing zone (ft)[1]	158.8	Calculated from da, aquifer thickness
I, Infiltration (ft/year)	0.00667	NDEP default, 0.08 inches/year = 0.00667 ft/year
L, Length (ft)	1500	Representative value for hypothetical source configuration
DAF[2]	96	

Notes:

1. Aquifer mixing zone depth d = (0.0112L^2)0.5 + da[1-exp(-LI/Kida)] (Equation 4 from BCL guidance)
   If d > da, use aquifer thickness instead of mixing zone thickness.
2. Dilution attenuation factor DAF = 1 + Kid / IL (Equation 3 from BCL guidance)

TABLE 4
Site-wide Soil to Groundwater Leaching Evaluation – Metals and Radionuclides

Chemical Name	Soil Zone[1]	Units	Count	Detect Count	Detect Frequency	Max Detect	Max Background	Above Background Site-wide?[2]	Detected in Groundwater Above RBGC?	Retained for Leaching Evaluation?	LBCL (DAF=1)	LBCL (DAF 20)	Detects > LBCL (DAF=20)	LSSL	Detects > LSSL	Detects > LBCL (DAF 20) after excavation[3]	Detects > LSSL after excavation[3]	Proposed for Additional Leaching Evaluation
Aluminum	Shallow	mg/kg	577	577	100%	20100	15300	No,p			7.5E+01	1.5E+03	575	>100% wt/wt	0	488	0	
Aluminum	Middle	mg/kg	349	349	100%	24700	15100	Yes	NO	YES	7.5E+01	1.5E+03	349	>100% wt/wt	0	349	0	NO
Aluminum	Deep	mg/kg	218	218	100%	31800	19700	Yes			7.5E+01	1.5E+03	218	>100% wt/wt	0	218	0	
Antimony	Shallow	mg/kg	568	280	49%	30	0.50	Yes			3.0E-01	6.0E+00	13	2.60E+01	2	2	0	
Antimony	Middle	mg/kg	348	196	56%	2.50	0.22	Yes	NO	YES	3.0E-01	6.0E+00	0	2.60E+01	0	0	0	NO
Antimony	Deep	mg/kg	212	99	47%	1.90	0.34	Yes			3.0E-01	6.0E+00	0	2.60E+01	0	0	0	
Arsenic	Shallow	mg/kg	577	577	100%	476	7.20	PASA			1.0E+00	2.0E+01	19	2.98E+01	13	1	0	
Arsenic	Middle	mg/kg	349	349	100%	223	13	Yes	YES	YES	1.0E+00	2.0E+01	79	2.98E+01	16	79	16	YES
Arsenic	Deep	mg/kg	218	218	100%	62	25	Yes			1.0E+00	2.0E+01	63	2.98E+01	9	63	9	
Barium	Shallow	mg/kg	579	579	100%	6760	465	PASA			8.20E+01	1.64E+03	7	1.00E+04	0	1	0	
Barium	Middle	mg/kg	349	349	100%	870	539	No,p	NO	YES	8.20E+01	1.64E+03	0	1.00E+04	0	0	0	NO
Barium	Deep	mg/kg	218	218	100%	1700	620	No,p			8.20E+01	1.64E+03	2	1.00E+04	0	2	0	
Beryllium	Shallow	mg/kg	577	577	100%	3.59	0.89	No,p			3.0E+00	6.0E+01	0	2.50E+02	0	0	0	
Beryllium	Middle	mg/kg	349	349	100%	1.24	0.67	PASA	NO	YES	3.0E+00	6.0E+01	0	2.50E+02	0	0	0	NO
Beryllium	Deep	mg/kg	218	218	100%	1.85	1.10	No			3.0E+00	6.0E+01	0	2.50E+02	0	0	0	
Boron	Shallow	mg/kg	577	541	94%	1510	12	Yes			2.34E+01	4.67E+02	8	2.17E+03	0	5	0	
Boron	Middle	mg/kg	349	331	95%	82	8	Yes	YES	YES	2.34E+01	4.67E+02	0	2.17E+03	0	0	0	NO
Boron	Deep	mg/kg	218	207	95%	85	23	Yes			2.34E+01	4.67E+02	0	2.17E+03	0	0	0	
Cadmium	Shallow	mg/kg	577	429	74%	21.40	0.16	Yes			4.0E-01	8.0E+00	2	2.06E+03	0	1	0	
Cadmium	Middle	mg/kg	349	261	75%	1.84	0.13	Yes	YES	YES	4.0E-01	8.0E+00	0	2.06E+03	0	0	0	NO
Cadmium	Deep	mg/kg	218	180	83%	1.04	0.20	Yes			4.0E-01	8.0E+00	0	2.06E+03	0	0	0	
Chromium (Total)	Shallow	mg/kg	579	579	100%	2760	17	Yes			2.0E+00	4.0E+01	29	NE	--	6	--	
Chromium (Total)	Middle	mg/kg	349	349	100%	102	17	Yes	--	NO	2.0E+00	4.0E+01	29	NE	--	29	--	NO
Chromium (Total)	Deep	mg/kg	218	218	100%	98	28	Yes			2.0E+00	4.0E+01	19	NE	--	19	--	
Chromium (VI)	Shallow	mg/kg	573	138	24%	131	ND	PASA			2.0E+00	4.0E+01	4	1.35E+02	0	1	0	
Chromium (VI)	Middle	mg/kg	348	78	22%	106	1.60	Yes	YES	YES	2.0E+00	4.0E+01	2	1.35E+02	0	2	0	NO
Chromium (VI)	Deep	mg/kg	216	36	17%	28.20	0.19	Yes			2.0E+00	4.0E+01	0	1.35E+02	0	0	0	
Cobalt	Shallow	mg/kg	577	577	100%	784	16	No,p			3.30E+01	6.60E+02	1	4.74E+01	9	0	3	
Cobalt	Middle	mg/kg	349	349	100%	284	11	No,p	YES	YES	3.30E+01	6.60E+02	0	4.74E+01	3	0	3	YES
Cobalt	Deep	mg/kg	218	218	100%	97	10	No,p			3.30E+01	6.60E+02	0	4.74E+01	1	0	1	
Copper	Shallow	mg/kg	577	577	100%	710	26	Yes			3.52E+01	7.04E+02	1	4.57E+03	0	0	0	
Copper	Middle	mg/kg	349	349	100%	77	24	PASA	NO	YES	3.52E+01	7.04E+02	0	4.57E+03	0	0	0	NO
Copper	Deep	mg/kg	218	218	100%	73	21	Yes			3.52E+01	7.04E+02	0	4.57E+03	0	0	0	
Iron	Shallow	mg/kg	577	577	100%	45600	19700	Yes			7.56E+00	1.51E+02	577	6.15E+04	0	489	0	
Iron	Middle	mg/kg	349	349	100%	21000	22500	No,p	YES	YES	7.56E+00	1.51E+02	349	6.15E+04	0	349	0	NO
Iron	Deep	mg/kg	218	218	100%	22200	20100	No			7.56E+00	1.51E+02	218	6.15E+04	0	218	0	
Lead	Shallow	mg/kg	579	579	100%	2540	35	Yes,1			NE	NE	--	1.30E+03	3	--	1	
Lead	Middle	mg/kg	349	349	100%	3280	16	No	YES	YES	NE	NE	--	1.30E+03	2	--	2	YES
Lead	Deep	mg/kg	218	218	100%	18	16	No,p			NE	NE	--	1.30E+03	0	--	0	
Magnesium	Shallow	mg/kg	577	574	99%	240000	17500	Yes			NE	NE	--	9.12E+04	9	--	1	
Magnesium	Middle	mg/kg	350	350	100%	72000	12500	Yes	YES	YES	NE	NE	--	9.12E+04	0	--	0	YES
Magnesium	Deep	mg/kg	218	216	99%	83000	31000	Yes			NE	NE	--	9.12E+04	0	--	0	
Manganese	Shallow	mg/kg	575	575	100%	70300	863	Yes			3.26E+00	6.52E+01	574	3.19E+03	28	486	14	
Manganese	Middle	mg/kg	347	347	100%	21600	579	PASA	YES	YES	3.26E+00	6.52E+01	347	3.19E+03	9	347	9	YES
Manganese	Deep	mg/kg	215	215	100%	1280	786	No			3.26E+00	6.52E+01	214	3.19E+03	0	214	0	
Mercury	Shallow	mg/kg	577	541	94%	34.20	0.11	Yes,1			1.04E-01	2.09E+00	1	1.95E+00	2	0	1	
Mercury	Middle	mg/kg	349	295	85%	0.19	0.02	PASA	NO	YES	1.04E-01	2.09E+00	0	1.95E+00	0	0	0	YES
Mercury	Deep	mg/kg	218	184	84%	0.19	0.01	Yes			1.04E-01	2.09E+00	0	1.95E+00	0	0	0	
Molybdenum	Shallow	mg/kg	577	573	99%	82.20	2.00	Yes			3.64E+00	7.27E+01	1	3.52E+02	0	0	0	
Molybdenum	Middle	mg/kg	349	348	100%	9.15	1.90	Yes,1	YES	YES	3.64E+00	7.27E+01	0	3.52E+02	0	0	0	NO

TABLE 4
Site-wide Soil to Groundwater Leaching Evaluation – Metals and Radionuclides

Chemical Name	Soil Zone[1]	Units	Count	Detect Count	Detect Frequency	Max Detect	Max Background	Above Background Site-wide?[2]	Detected in Groundwater Above RBGC?	Retained for Leaching Evaluation?	LBCL (DAF=1)	LBCL (DAF 20)	Detects > LBCL (DAF=20)	LSSL	Detects > LSSL	Detects > LBCL (DAF 20) after excavation[3]	Detects > LSSL after excavation[3]	Proposed for Additional Leaching Evaluation
Molybdenum	Deep	mg/kg	218	210	96%	3.19	1.10	Yes			3.64E+00	7.27E+01	0	3.52E+02	0	0	0	
Nickel	Shallow	mg/kg	577	577	100%	274	30	No,p			7.0E+00	1.40E+02	2	1.33E+05	0	0	0	
Nickel	Middle	mg/kg	349	349	100%	164	28	No,p	NO	NO	7.0E+00	1.40E+02	1	1.33E+05	0	1	0	NO
Nickel	Deep	mg/kg	218	218	100%	56	31	No,p			7.0E+00	1.40E+02	0	1.33E+05	0	0	0	
Platinum	Shallow	mg/kg	577	466	81%	1.00	0.10	PASA			NE	NE	--	NE	--	--	--	
Platinum	Middle	mg/kg	349	263	75%	0.03	0.05	PASA	--	NO	NE	NE	--	NE	--	--	--	NO
Platinum	Deep	mg/kg	218	171	78%	0.03	0.03	PASA			NE	NE	--	NE	--	--	--	
Potassium	Shallow	mg/kg	577	574	99%	12000	3890	Yes,1			NE	NE	--	NE	--	--	--	
Potassium	Middle	mg/kg	349	349	100%	6570	2450	Yes	--	NO	NE	NE	--	NE	--	--	--	NO
Potassium	Deep	mg/kg	218	213	98%	9190	6190	PASA			NE	NE	--	NE	--	--	--	
Selenium	Shallow	mg/kg	577	55	10%	3.50	0.60	PASA			3.0E-01	6.0E+00	0	1.44E+03	0	0	0	
Selenium	Middle	mg/kg	349	35	10%	1.70	ND	PASA	NO	YES	3.0E-01	6.0E+00	0	1.44E+03	0	0	0	NO
Selenium	Deep	mg/kg	218	30	14%	1.30	ND	PASA			3.0E-01	6.0E+00	0	1.44E+03	0	0	0	
Silver	Shallow	mg/kg	579	127	22%	9.60	0.08	Yes			2.0E+00	4.0E+01	0	1.93E+03	0	0	0	
Silver	Middle	mg/kg	349	71	20%	2.80	2.20	PASA	NO	YES	2.0E+00	4.0E+01	0	1.93E+03	0	0	0	NO
Silver	Deep	mg/kg	218	44	20%	0.60	0.82	PASA			2.0E+00	4.0E+01	0	1.93E+03	0	0	0	
Sodium	Shallow	mg/kg	577	574	99%	32200	1320	Yes			NE	NE	--	NE	--	--	--	
Sodium	Middle	mg/kg	349	349	100%	11700	3250	Yes	--	NO	NE	NE	--	NE	--	--	--	NO
Sodium	Deep	mg/kg	218	212	97%	11100	1200	Yes			NE	NE	--	NE	--	--	--	
Strontium	Shallow	mg/kg	577	576	100%	1570	808	No			NE	NE	--	7.38E+04	0	--	0	
Strontium	Middle	mg/kg	349	349	100%	4280	793	Yes	YES	YES	NE	NE	--	7.38E+04	0	--	0	NO
Strontium	Deep	mg/kg	218	214	98%	5670	324	No,p			NE	NE	--	7.38E+04	0	--	0	
Thallium	Shallow	mg/kg	579	545	94%	61.80	1.80	No,p			4.0E-01	8.0E+00	3	2.88E+02	0	1	0	
Thallium	Middle	mg/kg	349	321	92%	1.78	0.34	PASA	NO	YES	4.0E-01	8.0E+00	0	2.88E+02	0	0	0	NO
Thallium	Deep	mg/kg	218	210	96%	0.47	ND	PASA			4.0E-01	8.0E+00	0	2.88E+02	0	0	0	
Tin	Shallow	mg/kg	577	577	100%	24.20	0.80	Yes			NE	NE	--	5.26E+05	0	--	0	
Tin	Middle	mg/kg	349	349	100%	14.30	0.78	Yes	NO	YES	NE	NE	--	5.26E+05	0	--	0	NO
Tin	Deep	mg/kg	218	218	100%	36.20	0.96	Yes			NE	NE	--	5.26E+05	0	--	0	
Titanium	Shallow	mg/kg	577	577	100%	2480	1010	Yes			1.5E+05	3.0E+06	0	>100% wt/wt	0	0	0	
Titanium	Middle	mg/kg	349	349	100%	1180	912	PASA	NO	YES	1.5E+05	3.0E+06	0	>100% wt/wt	0	0	0	NO
Titanium	Deep	mg/kg	218	218	100%	1110	1000	Yes			1.5E+05	3.0E+06	0	>100% wt/wt	0	0	0	
Tungsten	Shallow	mg/kg	577	557	97%	158	ND	PASA			4.12E+01	8.23E+02	0	3.94E+03	0	0	0	
Tungsten	Middle	mg/kg	349	333	95%	15.70	3.60	Yes	YES	YES	4.12E+01	8.23E+02	0	3.94E+03	0	0	0	NO
Tungsten	Deep	mg/kg	218	211	97%	1.60	0.58	Yes			4.12E+01	8.23E+02	0	3.94E+03	0	0	0	
Uranium	Shallow	mg/kg	577	574	99%	9.64	2.70	Yes			1.35E+01	2.70E+02	0	1.30E+03	0	0	0	
Uranium	Middle	mg/kg	349	349	100%	55.20	2.80	Yes	YES	YES	1.35E+01	2.70E+02	0	1.30E+03	0	0	0	NO
Uranium	Deep	mg/kg	218	218	100%	19.20	4.40	Yes			1.35E+01	2.70E+02	0	1.30E+03	0	0	0	
Vanadium	Shallow	mg/kg	577	577	100%	205	59	Yes			3.0E+02	6.0E+03	0	1.75E+04	0	0	0	
Vanadium	Middle	mg/kg	349	349	100%	74	73	No,p	YES	YES	3.0E+02	6.0E+03	0	1.75E+04	0	0	0	NO
Vanadium	Deep	mg/kg	218	218	100%	60	46	Yes			3.0E+02	6.0E+03	0	1.75E+04	0	0	0	
Zinc	Shallow	mg/kg	577	577	100%	753	121	No,p			6.20E+02	1.24E+04	0	5.57E+05	0	0	0	
Zinc	Middle	mg/kg	349	343	98%	154	41	PASA	NO	YES	6.20E+02	1.24E+04	0	5.57E+05	0	0	0	NO
Zinc	Deep	mg/kg	218	216	99%	72	61	No			6.20E+02	1.24E+04	0	5.57E+05	0	0	0	
Ra-226	Shallow	pCi/g	508	499	98%	5.56	2.36	No,p			NE	NE	--	NE	--	--	--	
Ra-226	Middle	pCi/g	313	312	100%	11.00	2.29	PASA	--	NO	NE	NE	--	NE	--	--	--	NO
Ra-226	Deep	pCi/g	194	193	99%	11.10	1.63	Yes			NE	NE	--	NE	--	--	--	
Ra-228	Shallow	pCi/g	508	488	96%	4.84	2.92	No,p			NE	NE	--	NE	--	--	--	
Ra-228	Middle	pCi/g	313	307	98%	4.93	2.31	No,p	--	NO	NE	NE	--	NE	--	--	--	NO
Ra-228	Deep	pCi/g	194	192	99%	3.58	1.55	No			NE	NE	--	NE	--	--	--	
Ra-Total	Shallow	pCi/g	508	--	--	--	--	--			1.6E-02	3.2E-01	508	1.48E+00	430	436	372	

TABLE 4
Site-wide Soil to Groundwater Leaching Evaluation – Metals and Radionuclides

Chemical Name	Soil Zone[1]	Units	Count	Detect Count	Detect Frequency	Max Detect	Max Background	Above Background Site-wide?[2]	Detected in Groundwater Above RBGC?	Retained for Leaching Evaluation?	LBCL (DAF=1)	LBCL (DAF 20)	Detects > LBCL (DAF=20)	LSSL	Detects > LSSL	Detects > LBCL (DAF 20) after excavation[3]	Detects > LSSL after excavation[3]	Proposed for Additional Leaching Evaluation
Ra-Total	Middle	pCi/g	313	--	--	--	--	--	YES	YES	1.6E-02	3.2E-01	313	1.48E+00	301	313	301	YES
Ra-Total	Deep	pCi/g	194	--	--	--	--	--			1.6E-02	3.2E-01	194	1.48E+00	191	194	191	
Th-228	Shallow	pCi/g	508	508	100%	3.12	2.28	No,p			2.3E-03	4.5E-02	508	2.12E-01	506	436	435	
Th-228	Middle	pCi/g	313	313	100%	2.98	2.30	No,p	YES	NO	2.3E-03	4.5E-02	313	2.12E-01	313	313	313	NO
Th-228	Deep	pCi/g	194	194	100%	2.55	2.15	No			2.3E-03	4.5E-02	194	2.12E-01	194	194	194	
Th-230	Shallow	pCi/g	508	508	100%	14.80	3.01	No,p			8.4E-04	1.7E-02	508	8.10E-02	508	436	436	
Th-230	Middle	pCi/g	313	313	100%	10.80	2.72	Yes	YES	YES	8.4E-04	1.7E-02	313	8.10E-02	313	313	313	YES
Th-230	Deep	pCi/g	194	194	100%	7.94	2.09	Yes			8.4E-04	1.7E-02	194	8.10E-02	194	194	194	
Th-232	Shallow	pCi/g	508	508	100%	2.63	2.23	No,p			2.9E-03	5.8E-02	508	2.70E-01	505	436	435	
Th-232	Middle	pCi/g	313	313	100%	2.41	2.01	No,p	YES	NO	2.9E-03	5.8E-02	313	2.70E-01	313	313	313	NO
Th-232	Deep	pCi/g	194	194	100%	2.10	2.05	No,p			2.9E-03	5.8E-02	194	2.70E-01	194	194	194	
U-234	Shallow	pCi/g	508	508	100%	6.42	2.84	No,p			NE	NE	--	NE	--	--	--	
U-234	Middle	pCi/g	313	313	100%	14.30	2.63	Yes	--	NO	NE	NE	--	NE	--	--	--	NO
U-234	Deep	pCi/g	194	194	100%	7.55	1.81	Yes			NE	NE	--	NE	--	--	--	
U-235	Shallow	pCi/g	508	401	79%	0.31	0.21	No,p			NE	NE	--	NE	--	--	--	
U-235	Middle	pCi/g	313	283	90%	0.79	0.12	Yes	--	NO	NE	NE	--	NE	--	--	--	NO
U-235	Deep	pCi/g	194	175	90%	0.71	0.10	Yes			NE	NE	--	NE	--	--	--	
U-238	Shallow	pCi/g	508	508	100%	4.91	2.37	No,p			NE	NE	--	NE	--	--	--	
U-238	Middle	pCi/g	313	313	100%	12.50	2.79	Yes	--	NO	NE	NE	--	NE	--	--	--	NO
U-238	Deep	pCi/g	194	194	100%	23.00	1.75	Yes			NE	NE	--	NE	--	--	--	

Notes:

1: Shallow = 0-10 ft bgs including 10 ft; Middle = 10 ft - UMCf; Deep = UMCf

2: Background comparison notes:

No^p = Gilbert's Toolbox results imply Site data lower than Background data, additional analysis of Detection Limits is pending